Bird Density and Habitat Use in Forest Openings Created by Herbicides and Clearcutting in The Central Appalachians

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ABSTRACT.— Winter and breeding bird communities were sampled on clearcuts, on plots receiving four rates of picloram herbicide application, and on untreated plots. Four-year-old picloram treated plots did not increase bird species diversity, but did increase bird density over untreated plots. Positive response of some bird species to treatment was due to creation of an edge. Bird density was affected by physiographic site. Hairy woodpeckers, *Picoides villosus*; wintering red-bellied woodpeckers, *Melanerpes carolinus*; and Carolina chickadees, *Parus carolinensis*, used south-facing slopes more than north-facing slopes, while red-eyed vireos, *Vireo olivaceus*, and ovenbirds, *Seiurus aurocapillus*, used north-facing slopes more than ridgetop sites. White-breasted nuthatches, *Sitta carolinensis*; red-bellied woodpeckers; tufted titmice, *Parus bicolor*; and Carolina chickadees exhibited changes in habitat use from winter to spring. A variety of picloram herbicide treatments (27-68 kg/ha) and clearcutting in small (0.5-1.0 ha) blocks, on both south-facing and north-facing slopes, is recommended to increase bird density and provide more diverse habitat than exists in undisturbed forests.

INTRODUCTION

Herbicides are used by foresters for timber stand improvement and by wildlife managers to create forest openings (McCaffery et al. 1974; Loftis 1978; Dewey 1980). Any herbicide use or timber harvesting affects the structure and composition of forests as wildlife habitat. The effects of forest cutting on bird communities have been reported by McComb and Noble (1980), Strelke and Dickson (1980), and Crawford et al. (1981), who found that tree thinning tended to increase bird species diversity (BSD) and bird abundance, probably due to an increase in foliage height diversity of the stand. In contrast, little information is available on the effects of herbicide application on forest bird communities. Beaver (1976), Savidge (1978), and Best (1972) reported the effects of 2,4,5-T and 2,4-D applications to shrubs and trees on birds and found either no effects or reductions in bird density and/or diversity. Shipman (1972) reported greater wildlife diversity for up to 10 years after application of fenuron herbicide on 0.04-ha plots in Pennsylvania.

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Picloram-based herbicides are desirable for creating forest openings because of their low toxicity to many vertebrates (Kenaga 1969), but we could find no studies that compared bird use of picloram-created clearings with use of clearcut or uncut areas. Our objectives were to: 1) compare the relative abundance and diversity of winter birds and breeding birds among 4-year-old herbicide-created forest clearings, 4-year-old clearcuts, and mature untreated areas, 2) evaluate the effect of edge creation on bird use of habitats, and 3) identify the characteristics of habitats used by common species.

STUDY AREA AND METHODS

Snag Ridge Fork watershed, in the University of Kentucky's Robinson Forest, Knott and Breathitt counties, Kentucky, contains a second-growth mixed-mesophytic forest typical of much of the central Appalachians (Carpenter and Rumsey 1976). Ridges are dominated by shortleaf pine, *Pinus echinata*; pitch pine, *P. rigida*; chestnut oak, *Quercus prinus*; and scarlet oak, *Q. coccinea*. South-facing slopes are dominated by hickories, *Carya* spp.; white oak, *Q. alba*; black oak, *Q. velutina*; and sourwood, *Oxydendrum arboreum*. North-facing slopes are dominated by northern red oak, *Q. rubra*; cucumbertree, *Magnolia acuminata*; and yellow-poplar, *Liriodendron tulipifera*.

Fifteen of 18 0.4-ha square plots were treated in the watershed. This included four plots on each of a north-facing slope, south-facing slope, and ridge-top, which were randomly assigned one of the following hand-broadcast herbicide treatments applied in May 1976: 23 kg/ha TORDON 10k; 45 kg/ha TORDON 10K; 68 kg/ha TORDON 10K; or 90 kg/ha M-3864. TORDON 10K is a pelletized picloram-based (10% 4-amino-3,5,6-trichloropicolinic acid) herbicide and M-3864 is a 5% picloram pellet. (Mention of trade names is for identification and does not imply endorsement by the Kentucky Agricultural Experiment Station, Lexington.) A fifth plot on each aspect was clearcut (all stems cut, no residuals); fallen trees were not removed. A sixth plot on each aspect was established as a control in the untreated forest at least 75 m from any treated plot. Plots were located along the contour, and treated plots were 15 m to 50 m apart.

Fifteen stations were established perpendicular to the contour through the center of each plot. Thirty environmental characteristics (Table 1) chosen based on Anderson and Shugart (1974), Stauffer and Best (1980), and Crawford et al. (1981) were measured at each station. Estimates of cover of rocks, logs, leaves, canopy, and midstory followed methods described by James and Shugart (1971). Environmental characteristics other than understory vegetation were measured in May 1980. Understory vegetation was quantified on one 4-m^2 circular plot (radius = 1.2 m), 2 m away from each station along the contour in

Table 1. Habitat variables used in correlation analyses, bird habitat preference on clearcut, herbicide-treated and uncut plots, January to June 1980 and 1981, Knott County, Kentucky.

Description
Number of trees>10 cm dbh, within 2 m of a station.
Diameter of nearest tree (cm).
Distance to nearest tree (m).
Basal area of living stems (m^2/ha), wedge prism.
Number of snags>10 cm dbh, >1.8 m tall, within 2 m of a station.
Diameter of nearest snag (cm).
Distance to the nearest snag (m).
Number of stumps>10 cm in diameter and<1.8 m tall, within 2 m of a station.
Distance to the nearest stump (m).
Number of logs>10 cm diameter,>1.8 m long, within 2 m of a station.
Maximum diameter of the nearest log (cm).
Length of the nearest log (m).
Distance to the nearest log (m).
Percent of ground covered by logs within 2 m of a station.
Distance of the nearest rock>5 cm above ground.
Percent of ground covered by rocks within 2 m of a station.
Percent crown cover above 6.1 m at a station.
Percent vegetation cover between 1.8 and 6.1 m at a station.
Percent of the ground covered by fallen leaves within 2 m of a station.
Percent understory cover<1.8 m tall per 4-m^2 in Jan. and in Apr.
Number of understory stems per 4-m^2 in Jan. and in Apr.
Number of understory taxa per 4-m^2 in Jan. and in Apr.
Understory species diversity per 4-m^2 in Jan. and in Apr.
Distance to water (m).
Slope (%).
Foliage height diversity.

January and April of 1980. A modified Aldous method, similar to that described by Murphy and Noble (1972), was used to quantify vegetation. Percent cover and stem density were determined for each plant taxon (at least to genus) on each 4-m^2 plot. Total cover, total stem density, plant species richness, and a Shannon-Weaver plant species diversity index were calculated for each station for both sampling periods. April understory values were used in conjunction with May midstory and overstory values to calculate a foliage height diversity index based on estimated cover of the three layers. Mean habitat characteristics were calculated for each 0.4-ha plot and used to characterize the plot. A more detailed discussion of habitat characteristics was given by McComb and Rumsey (in press).

Birds were counted 15 times on each 0.4-ha plot from 15 January to 5 March 1980 and 1981 (winter birds), and 13 times on each plot from 20 March to 15 June 1980 and 1981 (breeding birds). Approximately 10 minutes were spent on the center of each plot during each visit counting birds seen or heard on the plot. Locations of birds in the plot were judged to be within 9 m of the plot edge or within the plot center. Only winter birds observed foraging were assumed using a plot while breeding birds which were either singing or foraging were tallied. Birds were counted within three hours of sunrise or sunset. Eight morning and seven evening visits were made to each plot during winter, and seven morning and six evening visits were made to each plot during the breeding season. Shannon-Weaver BSD, equitability, richness, and average density per plot per visit of each species were compared among treatments blocking on aspects with analysis of variance and Duncan's New Multiple Range Test. Tests among treatments are conservative due to variability among aspects. Linear correlation was used to identify plot characteristics potentially important in determining use by common bird species. A t-test was used to compare weighted mean environmental characteristics for plots used by a species vs. overall means and to compare mean BSD, equitability, richness, and density between seasons. Chi-square analysis was used to compare occurrences of birds at the edge vs. center of plots.

RESULTS AND DISCUSSION

Seasonal Effects.— Not unexpectedly, the breeding bird communities had higher diversity ($\bar{x}$ = 0.911), richness ($\bar{x}$ = 2.2), equitability ($\bar{x}$ = 0.238), and density ($\bar{x}$ = 2.4 birds/0.4 ha) than the winter bird communities ($\bar{x}$ = 0.265, 1.0, 0.069, and 1.0, respectively) (Table 2). Winter bird communities were dominated by hairy woodpeckers, *Picoides villosus*, and Carolina chickadees, *Parus carolinensis* (Table 2), and the breeding bird communities were dominated by red-eyed vireos, *Vireo olivaceus*, and hooded warblers, *Wilsonia citrina* (Table 3). Several resident species changed their habitat usage from winter to spring. White-breasted nuthatches, *Sitta carolinensis*, used areas in spring with a higher density ($\bar{x}$ = 1/43 m^2) of larger diameter ($\bar{x}$ = 1.23 cm) snags and fewer trees ($\bar{x}$ = 1/32 m^2) than in winter ($\bar{x}$ = 1/171 m^2, 7.9 cm and 1/27 m^2, respectively) ($\underline{P}<0.05$). Red-bellied woodpeckers, *Melanerpes carolinus*, used areas in spring with more snags ($\bar{x}$ = 1/50 m^2), higher understory density ($\bar{x}$ = 45.2 stems/4 m^2), and lower foliage height diversity ($\bar{x}$ = 1.23) than in winter ($\bar{x}$ = 1/171 m^2, 34.7 stems/4 m^2, and 1.40, respectively) ($\underline{P}<0.05$). Both white-breasted nuthatches and red-bellied woodpeckers probably used areas with higher snag density in spring for nesting purposes, since both will forage on dead or living trees in the winter (Conner 1979).

Table 2. Birds observed in 15 visits to each treatment, 15 January to 5 March, 1980 and 1981, Knott County, Kentucky.

Species	Control	Clearcut	Herbicide (kg/ha) 23	45	68	90	TOTAL
hairy woodpecker *Picoides villosus*	6	7	11	11	8	6	49
Carolina chickadee *Parus carolinensis*	7	10	8	10	6	5	46
tufted titmouse *Parus bicolor*	5	2	5	4	2	3	21
white-breasted nuthatch *Sitta carolinensis*	2B[a]	OB	4AB	8A	3B	3B	20
red-bellied woodpecker *Melanerpes carolinus*	2	3	3	5	3	1	17
northern cardinal *Cardinalis cardinalis*	OB	7A	5AB	1	1B	1B	15
rufous-sided towhee *Pipilo erythrophthalmus*	OB	10A	OB	OB	OB	OB	10
Number of other individuals	2	4	8	8	9	11	42
Number of other species[b]	2	2	3	3	5	7	13
Total individuals	24B	43A	44A	47A	32AB	30AB	220
Total species	7	8	9	9	11	13	20
Bird species diversity	0.193	0.305	0.375	0.373	0.174	0.168	0.265
Equitability	0.050	0.080	0.098	0.097	0.045	0.044	0.069

[a] Values (analyzed as means) with different letters vary significantly, $\underline{P}<0.05$.

[b] Pileated woodpecker, *Dryocopus pileatus*; downy woodpecker, *Picoides pubescens*; yellow-bellied sapsucker, *Sphyrapicus varius*; common flicker, *Colaptes auratus*; red-tailed hawk, *Buteo jamaicensis*; ruffed grouse, *Bonasa umbellus*; brown creeper, *Certhia familiaris*; blue jay, *Cyanocitta cristata*; turkey vulture, *Cathartes aura*; ruby-crowned kinglet, *Regulus calendula*; golden-crowned kinglet, *Regulus satrapa*; northern junco, *Junco hyemalis*; and white-throated sparrow, *Zonothrichia albicollis*.

Table 3. Birds observed in 13 visits to each treatment, 20 March to 15 June, 1980 and 1981, Knott County, Kentucky.

Species	Control	Clearcut	Herbicide (kg/ha)				TOTAL
			23	45	68	90	
red-eyed vireo *Vireo olivaceus*	16	7	14	11	12	10	70
hooded warbler *Wilsonia citrina*	4	12	10	8	6	9	49
black-throated green warbler *Dendroicia virens*	4	1	4	1	6	1	17
ovenbvird *Seiurus aurocapillus*	5A[a]	OB	2AB	3AB	OB	5A	15
black-and-white warbler *Mniotilta varia*	1	2	7	3	1	2	16
Kentucky warbler *Oporornis formosus*	OB	OB	3AB	2AB	6A	4AB	15
Carolina chickadee *Parus carolinensis*	0	2	5	4	3	0	14
hairy woodpecker *Picoides villosus*	2	0	6	3	2	1	14
tufted titmouse *Parus bicolor*	OB	2B	3B	3B	5A	OB	13

red-bellied woodpecker *Melanerpes carolinus*	4A	0B	0B	4A	1AB	1AB	10
Number of other individuals	10	25	17	17	19	16	104
Number of other species[b]	10	12	11	8	10	13	22
Total individuals	46B	51B	71A	59AB	61AB	49B	337
Total species	17	18	20	18	19	21	32
Bird species diversity	0.768	0.771	1.040	0.955	1.087	0.845	0.911
Equitability	0.201	0.201	0.271	0.250	0.284	0.221	0.238

[a] Values (analyzed as means) with different letters vary significantly, $P \le 0.05$.

[b] American woodcock, *Philohela minor*; ruffed grouse, *Bonasa umbellus*; yellow-billed cuckoo, *Coccyzus americanus*; pileated woodpecker, *Dryocopus pileatus*; downy woodpecker, *Picoides pubescens*; Acadian flycatcher, *Empidonax virescens*; eastern pewee, *Contopus virens*; white-breasted nuthatch, *Sitta carolinensis*; brown creeper, *Certhia familiaris*; blue-gray gnatcatcher, *Polioptila caerulea*; wood thrush, *Hylocichla mustelina*; warbling vireo, *Vireo gilvus*; white-eyed vireo, *Vireo griseus*; northern parula warbler, *Parula americana*; cerulean warbler, *Dendroica cerulea*; American redstart, *Setophaga ruticilla*; yellow warbler, *Dendroica petechia*; worm-eating warbler, *Helmitheros vermivorus*; scarlet tanager, *Piranga olivacea*; summer tanager, *Piranga rubra*; indigo bunting, *Passerina cyanea*; and rufous-sided towhee, *Pipilo erythrophthalmus*.

Carolina chickadees used areas with greater ($\underline{P}$<0.05) understory species richness in the spring ($\bar{x}$ = 7.3 species/4 m^2) than in the winter ($\bar{x}$ = 6.6), and tufted titmice used areas with lower ($\underline{P}$<0.05) leaf cover (a more open canopy) ($\bar{x}$ = 46.4%) in the spring than in the winter ($\bar{x}$ = 63.5%).

Winter Birds.— Bird species diversity, equitability, and richness did not vary significantly among treatments nor among aspects ($\underline{P}$>0.05). Winter bird density was higher on clearcuts, 23 kg/ha, and 45 kg/ha plots than on the control plots ($\underline{P}$<0.05) (Table 2), and bird density on ridge-tops ($\bar{x}$ = 1.1 bird/plot/visit) ($\underline{P}$<0.05) was higher than on north facing slopes ($\bar{x}$ = 0.53 birds/plot/visit) ($\underline{P}$<0.05). South-facing and ridgetop areas are warmer than north-facing slopes throughout the daylight hours and probably influenced bird activity (Shields and Grubb 1974).

Hairy woodpecker abundance was similar among treatments, but they used south-facing slopes (17 individuals) more than north-facing slopes (7 individuals), and they were observed using plot edges (20 individuals) more than plot centers (4 individuals) ($\underline{P}$<0.05). Carolina chickadee abundance was similar among treatments, but they used ridge-tops (25 individuals) more than north-facing slopes (5 individuals) ($\underline{P}$<0.05). Strelke and Dickson (1980) found breeding Carolina chickadees associated with pine-hardwood clearcut edges in Texas. Carolina chickadee numbers were correlated with distance to the nearest stump (r =+ 50.6), slope (r =– 50.5), and understory density (r =+ 49.4) ($\underline{P}$< 0.05). Distance to stumps on plots used by chickadees (23.2 m; SD = 7.1) differed significantly ($\underline{P}$<0.05) from overall stump distance (17.4 m; SD = 7.9). Large, soft stumps may afford roosting sites for chickadees.

White-breasted nuthatch abundance was similar among aspects ($\underline{P}$>0.05), but more individuals were observed on 45 kg/ha plots than on any other treatment except 23 kg/ha plots ($\underline{P}$<0.05) (Table 2). White-breasted nuthatch numbers were correlated with log length (r = + 51.1). Log presence indicates prior snag presence so nuthatches may be using an area that recently had snags present. Plots used by wintering white-breasted nuthatches had higher crown cover ($\bar{x}$ = 57.5%), lower understory diversity ($\bar{x}$ = 4.73), and lower understory density ($\bar{x}$ = 26.3 stems/4 m^2) than overall plot means ($\bar{x}$ = 31.6, 5.15, and 36.2, respectively). Wintering white-breasted nuthatches occurred on plots with open crowns, sparse understory, and many long logs on the ground.

Red-bellied woodpeckers used ridge-tops (13 individuals) more than south- or north-facing slopes (2 individuals each) and they were found more frequently at plot edges (12 individuals) than centers (5 individuals) ($\underline{P}$<0.05). Red-bellied woodpecker numbers were negatively correlated with slope (r = 45.7), a result of their use of ridge sites.

Wintering northern cardinals, *Cardinalis cardinalis*, used clearcuts more than other treatments except 23 kg/ha plots ($\underline{P}<0.05$) (Table 2). Both treatments resulted in dense understory vegetation (>100%) and low basal area (<17.5 m^2/ha). Cardinals showed no association with edge. Northern cardinal abundance was correlated with snag and tree distance (r =+ 62.4, + 57.7), and basal area (r =- 54.1). Snags provide singing perches for cardinals.

Rufous-sided towhees, *Pipilo erythrophthalmus*, used clearcuts more than any other treatment ($\underline{P}<0.05$) (Table 2). Clearcuts had the lowest basal area (9.3 m^2/ha 4-year-old regrowth) and the highest ground cover (logs, 3.5/12 m^2; rocks, 6.7% cover; stumps, 0.8/12 m^2) of any of the plots. Towhee numbers were correlated with distance to the nearest tree (r =+ 80.0) and basal area (r =- 70.3) ($\underline{P}<0.01$). Trees near young clearcuts probably provide singing perches for towhees. These results concur with those of Crawford et al. (1981) and Conner and Adkisson (1975).

Sample sizes for 13 other winter resident species were too small to detect meaningful differences among treatments or aspects (Table 2).

Breeding Birds.— We found no differences in BSD or equitability among treatments or aspects ($\underline{P}>0.05$). Average breeding bird density was higher on 23 kg/ha plots than on other treatments except 45 and 68 kg/ha plots ($\underline{P}<0.05$) (Table 3). Density was higher on south- and north-facing slopes ($\bar{x}$ = 1.6 birds/plot/visit) than on ridge-tops ($\bar{x}$ = 1.2 birds/plot/visit) ($\underline{P}<0.05$). Smith (1977) reported that moist forests were of more importance to most species of breeding birds in Arkansas than extremely dry sites.

The red-eyed vireo was the most abundant species and it used south- and north-facing slopes (31 and 26 individuals) more than ridge-tops (13 individuals), and edges (54 individuals) more than centers (16 individuals) ($\underline{P}<0.05$). Because edges of most plots had more complete canopy development than plot centers (except control plots), it is not surprising that red-eyed vireos used edges. Anderson and Shugart (1974), Stauffer and Best (1980), and Crawford et al. (1981) reported red-eyed vireos associated with closed canopies and sparse understory. We also found that red-eyed vireo numbers were correlated with tree density (r =+ 47.8).

Hooded warblers, *Wilsonia citrina*, were ubiquitous over treatments and aspects. Plots used by hooded warblers had lower basal area ($\bar{x}$ = 7.1 m^2/ha) than plots not used (18.6 m^2/ha) ($\underline{P}<0.05$). Occurrence of hooded warblers was associated with understory diversity (r =+ 59.3) and understory density (+ 50.1), similar to Anderson and Shugart's (1974) findings.

Black-throated green warblers, *Dendroica virens*, were ubiquitous over treatments and aspects. Plots used by black-throated green warblers had less leaf cover ($\bar{x}$ = 26.4%) (hence lower crown cover), greater slope ($\bar{x}$ = 49.0%), and higher understory diversity ($\bar{x}$ = 5.49) than overall plot averages ($\bar{x}$ = 56.0, 36.2, and 5.15, respectively). Freedman et al. (1981) reported adverse effects of forest cutting on black-throated green warblers in Nova Scotia, but we found this species tolerant of forest disturbance in Kentucky, though densities were low on clearcut, 45 kg/ha and 90 kg/ha plots.

Ovenbirds, *Seiurus aurocapillus*, used control and 90 kg/ha plots more than clearcut and 68 kg/ha plots ($\underline{P}<0.05$) (Table 3). The 90 kg/ha of M-3864 resulted in dense understory ($\bar{x}$ = 105%), partial midstory ($\bar{x}$ = 13%), and a discontinuous overstory ($\bar{x}$ = 31.9%) (McComb and Rumsey, in press). Further, ovenbirds used edges more frequently (13 individuals) than plot centers (2 individuals) ($\underline{P}<0.05$), and they were found more often on north-facing slopes (10 individuals) than on ridges (1 individual) ($\underline{P}<0.05$). Allaire (1978), Robbins (1979), Stauffer and Best (1980) and Crawford et al. (1981) indicated that ovenbirds are a forest interior species and that they are adversely affected by forest disturbance or edge presence, but our study and that of Freedman et al. (1981) indicated that ovenbirds will occur on edges of some disturbed areas surrounded by undisturbed forest. Plots where ovenbirds occurred in our study had higher crown cover ($\bar{x}$ = 49.7%), leaf cover ($\bar{x}$ = 73.2%), basal area ($\bar{x}$ = 41.7 m^2/ha), foliage height diversity ($\bar{x}$ = 1.44), lower log density ($\bar{x}$ = 0.8/12 m^2), and a shorter distance to water ($\bar{x}$ = 189.8 m) than overall plot means ($\bar{x}$ = 31.5, 56.0, 33.3, 1.30, 1.5, and 335.7, respectively). Ovenbird numbers were correlated with basal area (r = + 54.6), crown cover (r =+ 48.0), and distance to water (r =− 47.1).

Kentucky warblers, *Oporornis formosus*, used 68 kg/ha plots more than control and clearcut plots ($\underline{P}<0.05$) (Table 3). Abundant ($\bar{x}$ = 1/31 m^2) and large-diameter ($\bar{x}$ = 34.8 cm) snags, low basal area (17.2 m^2/ha), and low midstory cover (17.1%) characterized 68 kg/ha plots. Kentucky warblers were found on plots with higher snag density ($\bar{x}$ = 1/13 m^2), rock cover ($\bar{x}$ = 8.8%), and lower midstory cover ($\bar{x}$ = 15.5%), snag distance ($\bar{x}$ = 16.2 m), rock distance ($\bar{x}$ = 14.9 m), and log length ($\bar{x}$ = 19.7 m), than overall averages ($\bar{x}$ = 1/20, 3.3, 28.0, 3.4, 32.8, and 28.4, respectively). Kentucky warbler numbers were correlated with midstory cover (r =− 52.3) and snag diameter (r =+ 48.6). Kentucky warbler habitat on our plots was characterized by many logs, rocks and large snags and little midstory on sites away from permanent water. Log and rock presence may be important as a nest location for this ground-nesting species.

Tufted titmice had no association with aspect or edge, but they were observed most frequently on 68 kg/ha plots ($\underline{P}<0.05$) (Table 3). The abundance of large-diameter snags ($\bar{x}$ = 34.8 cm dbh) that occurred on 68 kg/ha plots may have influenced use of these plots by this cavity-nesting species. Stauffer and Best (1980) reported this species tolerant of habitat disturbance and Crawford et al. (1981) found titmice using a wide range of habitats.

Red-bellied woodpeckers used control and 45 kg/ha plots more frequently than clearcut or 23 kg/ha plots ($P<0.05$) (Table 3). Control and 45 kg/ha plots were characterized by having higher basal area ($\bar{x}$ = 22.5 m^2/ha) than either clearcut (9.3 m^2/ha) or 23 kg/ha plots (17.5 m^2/ha). Red-bellied woodpeckers exhibited no association with aspect or edge, but hairy woodpeckers used ridge-tops (9 individuals) more ($P<0.05$) than north- or south-facing slopes (3 and 2 individuals, respectively). Red-bellied woodpeckers used habitats with an open understory (high crown cover) and high basal area.

Sample sizes were insufficient to identify treatment, aspect, or habitat preferences of 22 other species of breeding birds encountered during the course of our study (Table 3).

MANAGEMENT IMPLICATIONS

Long-term effects of picloram herbicide application in field situations on soil invertebrates, invertebrates inhabiting herbicide-created snags, plant succession, and reproductive physiology of terrestrial vertebrates have not been thoroughly investigated. If future studies indicate minimal effects of picloram herbicides on these ecological processes, then pelletized picloram application may be a more desirable and less expensive non-game bird management tool in remote or rugged terrain than manually cutting trees. Four years after application of picloram herbicide or clearcutting, increases in BSD through changes in species composition and increased density of some species in the forest may be expected, but no single treatment will accomplish this goal. Although we found no differences in BSD among treatments, some species preferred or occurred exclusively on one or several treatments.

Total bird density was higher on treated plots than control plots in both winter and spring. This may have been due to the presence of edge for some species (wintering hairy and red-bellied woodpeckers, red-eyed vireos, and ovenbirds) and/or to the changes in the biotic and abiotic habitat characteristics produced by the treatment. For instance, changes in habitat characteristics due to clearcutting produced predictable occurrences of rufous-sided towhees and cardinals. Changes in habitat structure brought about by herbicide application allowed predictable occurences of some species (e.g., Kentucky warblers and ovenbirds) but not others (black-throated green warblers and tufted titmice).

We recommend that a range of pelletized picloram rates from 27 to 68 kg/ha be used on small plots (0.5 - 1.0 ha) in conjunction with small clearcuts to provide desirable habitat requirements for as many species of birds as possible, and to increase the density of many of these species over what would occur in an undisturbed forest. Ninety kg/ha of M-3864 was not a desirable treatment since none of the species used plots with this rate over one of the other treatments. If ten plots per 1,000 ha were treated each year, habitat would be provided on a sustained basis while allowing 100 years for recovery on each site. Herbicide-treated plots and clearcuts placed on both north-facing and south-facing slopes would increase the advantages to breeding migrants and wintering residents or breeding Picids, respectively.

ACKNOWLEDGMENTS.— We wish to thank R. L. Anderson, D. M. Allen, M. J. Immel, and C. Rowell for advice on statistical analyses; Dow Chemical Corp. for supplying herbicides; J. B. Davis and the Robinson Forest staff for assistance with field work; and R. N. Conner, P. D. Doerr, B. A. Thielges, P. N. Allaire, R. E. Noble, R. B. Hamilton, R. D. Shipman, R. N. Muller, and C. J. Liu for reviewing an early draft of the manuscript. The investigation reported in this manuscript (No. 82-8-40) is in connection with Kentucky Agricultural Experiment Station Project No. 620 and is published with the approval of the Director.

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Accepted 29 April 1983